AD-A103 739 COLD REGIONS RESEARCH AND ENGINEERING LAB HANOVER NH F/G 13/2
SEVEN-YEAR PERFORMANCE OF CRREL SLOW-RATE LAND TREATMENT PROTOT--ETC(U)
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Special Report 81-12

July 1981

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SEVEN-YEAR PERFORMANCE OF CRREL SLOW-RATE LAND TREATMENT PROTOTYPES

T.F. Jenkins, A.J. Palazzo, P.W. Schumacher, H.E. Hare,
P.L. Butler, C.J. Diener and J.M. Graham

Prepared for
DIRECTORATE OF CIVIL WORKS
OFFICE OF THE CHIEF OF ENGINEERS

by

UNITED STATES ARMY CORPS OF ENGINEERS
COLD REGIONS RESEARCH AND ENGINEERING LABORATORY
HANOVER, NEW HAMPSHIRE, U.S.A.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER (14) CRREL-SR- Special Report 81-12	2. GOVT ACCESSION NO. AD-A103 739	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) (6) SEVEN-YEAR PERFORMANCE OF CRREL SLOW-RATE LAND TREATMENT PROTOTYPES.	5. TYPE OF REPORT & PERIOD COVERED (7) Final
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) T.F. Jenkins, A.J. Palazzo, P.W. Schumacher, H.E. Hare, P.L. Butler, C.J. Diener and J.M. Graham	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Cold Regions Research and Engineering Laboratory Hanover, New Hampshire 03755	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS CWIS 31297
11. CONTROLLING OFFICE NAME AND ADDRESS (11) Directorate of Civil Works Office of the Chief of Engineers Washington, D.C. 20314	12. REPORT DATE July 1981
	13. NUMBER OF PAGES 29
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) (12) 29	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

(10) Thomas F. /Jenkins Antonio J. /Palazzo
Patricia W. /Schumacher Helen E. /Hare
Patricia L. /Butler

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Chemical analysis
Cold regions
Land treatment
Overland flow
Wastewater treatment

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A set of six outdoor, slow-rate land treatment prototypes was operated from June 1973 through May 1980. Water quantity and quality data are presented for the wastewater applied to and the percolate leaving the 5-foot soil profile. Average concentration, mass loading and mass and percentage removal of wastewater constituents are presented on a yearly basis.

Tabulations of crop production and nutrient uptake are also presented. Nutrient balance sheets summarize the relative amounts removed by plant uptake, deep percolation and other removal mechanisms for nitrogen and phosphorus.

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AD-A103739

PREFACE

This report was prepared by Thomas F. Jenkins, Research Chemist, Earth Sciences Branch (ESB), Research Division; Antonio J. Palazzo, Research Agronomist, ESB; Patricia W. Schumacher, Physical Science Technician, ESB; Helen E. Hare, Physical Sciences Aid, ESB; John M. Graham, Biological Technician, ESB; Patricia L. Butler, Civil Engineering Technician, Civil Engineering Research Branch (CERB), Experimental Engineering Division; and Carl J. Diener, Civil Engineering Technician, CERB.

This study was conducted as a part of the U.S. Army Corps of Engineers Civil Works Research and Investigations Project under Work Unit CWIS 31297, Optimization of Management Techniques for Wastewater Renovation.

The results presented in this data report represent a very large effort not only by the authors but also by many other individuals at CRREL. The authors acknowledge Sherwood Reed, Dr. Paul Murrmann, Warren Rickard, Bruce Brockett and Timothy Buzzell for the initial design of the CRREL Land Treatment Facility, including the outdoor prototypes known as the test cells; Dr. Harlan McKim for his technical and administrative support in the role of Program Manager; Daniel Leggett for method development in the water chemistry laboratory; Roy Bates and the U.S. Army Meteorological Support Team for maintaining climatic surveillance; Dr. I.K. Iskandar and John Bouzoun for useful technical discussions; Robert Sletten and C. James Martel for supervision of the pretreatment facility; Pat Ricard for outstanding technical support as chief technician in the water quality laboratory for the first three years of the effort; Donald Keller, Arthur Gidney and Jack Bayer for operation of the CRREL sewage treatment plant and test cells in the first five years; Steven Quarry for providing data on major cations; Bruce Ashley for assistance in the laboratory; and a large number of part-time students, including Brian Foley, Kathy Norwood, Susan Myers, Donna Kakimoto, William Immel, Ellen Foley, Steve Green, Dennis Albaugh, Steve Brady, Lee Henrikson, Lee Jones, Janice Lee, Steve Zebrowski, Katy Weeks, Karen Roy, and Martin Leamon, who performed in an outstanding manner as analysts in the water quality laboratory; Jane Mason, Lydia Bos, Holt Audrey and Wayne Hannel for careful data handling in the storage/retrieval system; and Edward Gerard for assistance in the day-to-day operation of the greenhouse and test cells. This report was technically reviewed by Mr. Reed and Dr. Iskandar.

LIST OF TABLES

SEVEN-YEAR PERFORMANCE OF CRREL SLOW-RATE LAND TREATMENT PROTOTYPES

T.F. Jenkins, A.J. Palazzo, P.W. Schumacher,
H.E. Hare, P.L. Butler, C.J. Diener and J.M. Graham

INTRODUCTION

Construction of the CRREL slow-rate land treatment facility was completed in the spring of 1973. This facility included a set of six prototypes (referred to as test cells), a large greenhouse, and primary and secondary wastewater treatment plants. The test cells were packed with 5 feet of either Windsor sandy loam or Charlton silt loam soil. They were enclosed with reinforced concrete on the sides and bottom and sloped to a drain so that all the water passing through the soil profile could be measured and representative samples collected. The surface of the cells was seeded with a forage grass mixture (Palazzo 1976). A detailed description of the design and construction of the test cells is available in reports by Iskandar et al. (1976) and Jenkins and Palazzo (in press).

Primary or secondary wastewater was applied to all six prototypes from June 1973 to May 1978. From June 1978 to May 1980, wastewater applications continued on the test cells, but only for Test Cells 1 and 6 were careful monitoring activities continued. Test Cells 2-5 were used for short-term destructive tests over this period, and hence their behavior, with the exception of water balance measurements, is not useful for assessing long-term performance.

The first year of wastewater application (June 1973-May 1974) was considered a preliminary experiment and was used to test procedures and analytical methods. The water volumes for the test cell percolates were not measured in this initial year, and hence mass balancing of wastewater nutrients was not possible.

Several reports on this project have been published. An interpretive report by Iskandar et al. (1976) examined the behavior of the test cells during the period June 1974-May 1975. Jenkins et al. (1978)[1] presented

[1] Several errors in water volumes were discovered in that publication and have been corrected in this report.

the annually averaged water quality, water balance and plant data for June 1973-May 1978. Soil information and climatic measurements for 1973-1978 were presented by Iskandar et al. (1979). A report analyzing the complete results over the period June 1973-May 1980 is currently in press (Jenkins and Palazzo 1981). All the individual measurements for water quality, soils, plants and climate are maintained on magnetic tape at the CRREL computer center.

The purpose of this report is to correct and update the previous reports by presenting in a concise, usable fashion the annual water quality, water balance and plant data for the seven-year study.

RESULTS

The types of wastewater and the weekly loading rates for each test cell for 1973-1980 are presented in Table 1. Application rates varied from a high of 15 cm per week for Cell 2 in 1974-76 to the constant 5 cm per week used for Cells 1 and 6 throughout the experiment. From June 1976 to May 1977 the weekly application rate on Cells 2-5 was varied over the growing season in an attempt to match the plant uptake cycle. Applications were generally made over 8-hour periods except for Cell 5 in 1974-76, where a 24-hour application period was used.

Due to variability in the weather and specific study requirements, the time of year during which wastewater was applied to the test cells varied considerably (Table 2). For example, Cell 1 received wastewater throughout the winter of 1974-75, as did Cell 6 in 1974-75 and 1975-76, while applications to all cells ceased in September for the winter of 1977-78 (Table 2).

A unique feature of the CRREL test cells is that the volume of water applied to and percolating through the cells can be monitored. In addition, rainfall and evaporation were measured from June 1974 to May 1980, enabling an accurate water balance to be calculated for this period (Table 3). Rainfall measurements were converted from centimeters to liters using a test cell surface area of 76.79 m^2, which includes the contribution from one half of the surface area of the concrete side walls. Conversion of evaporation data to volume was done using a surface area of 72.836 m^2, the vegetated surface area of the test cells.

Representative samples of the wastewaters applied to the test cells were analyzed each week for a number of parameters. Composite samples of test cell percolates were also collected and analyzed at a frequency which varied from about three times per week in 1974-75 to once per week in 1979-80. Annual (volume-weighted) averages for each type of analysis are given for each test cell in Table 4. Results reported for pH are median values due to the logarithmic nature of the pH measurement. The values given for percolate pH, Ca^{++}, Na^{+}, K^{+}, Mg^{++} and conductivity were actually obtained on samples collected at 46 cm with suction lysimeters.

The forage grasses that were grown on the test cells were harvested three times per year from 1973 through 1980, with several exceptions. Only two harvests were taken on all cells in 1973 because of the time required to establish a grass cover after initial seeding. In 1976 only one harvest was obtained for Cells 2-5 because the surface of these cells was tilled and reseeded. The harvest yields for each cell are given in Table 5. The yield values are for dry-weight production in the 38.60 m^2 area (the area of the 23-ft-diameter spray circles). The concentrations of nitrogen (N), phosphorus (P) and potassium (K) were determined commercially for representative samples of the dry matter produced by the plants (Table 5). The masses of N and P, reported in kg/cell, were calculated by multiplying the amount of dry matter by the concentration. The uptake of N and P is converted to kg/ha using a surface area of 38.60 m^2. Plant concentrations of K, protein and total digestible nutrients are shown in Tables 6 and 7.

Using the water volume data from Table 3 and the concentrations in Table 4, we can calculate the masses of N and P applied to and percolating from the test cells. These values for each year are given in Table 8 in kg/cell. Also included in Table 8 are the masses of N and P removed by the grass and the N and P not accounted for in either percolate or plant uptake, which should be the N and P removed by other mechanisms.

The quantities of soil amendments (lime, P and K) applied to the test cells from 1973 to 1980 are shown in Table 9. The dolomitic limestone, which was used to alleviate soil acidity problems, also contains Ca and Mg,

which are required for plant growth. Potassium was applied as KCl fertilizer. The following equation, which was developed at CRREL (Palazzo and Jenkins 1979), was used to determine K needs after 1977:

$$K_f = 0.9\ U - K_{ww}$$

where

K_f = annual amount of potassium fertilizer applied in the spring (in kg/ha)

U = estimated annual crop uptake of nitrogen (in kg/ha)

K_{ww} = amount of potassium to be applied in the wastewater (in kg/ha).

Phosphorus was applied as superphosphate fertilizer to promote grass establishment on the reconditioned test cells in 1976.

In the last year of the project it was decided to test the capability of the test cells for removing volatile toxic organics. Since the waste stream used to supply wastewater for this project was domestic in character, it had very little of these substances present. We therefore "spiked" the sewage with a number of these substances and studied their removal by sampling the wastewater (before and after spraying) and the percolates. The results of these tests are given in Table 10.

LITERATURE CITED

Iskandar, I.K., S.T. Quarry, R.E. Bates and J. Ingersoll (1979) Documentation of soil characteristics and climatology during five years of wastewater application to CRREL test cells. CRREL Special Report 79-23.

Iskandar, I.K., R.S. Sletten, D.C. Leggett and T.F. Jenkins (1976) Wastewater renovation by a prototype slow infiltration land treatment system. CRREL Report 76-19.

Jenkins, T.F. and A.J. Palazzo (1981) Wastewater treatment by a prototype slow rate land treatment system. CRREL Report 81-14.

Jenkins, T.F. et al. (1978) Five-year performance of CRREL land treatment test cells. CRREL Special Report 78-26.

Palazzo, A.J. (1976) Effects of wastewater application on the growth and chemical composition of forages. CRREL Report 76-39.

Palazzo, A.J. and T.F. Jenkins (1979) Land application of wastewater: Effect on soil and plant potassium. Journal of Environmental Quality, vol. 8, no. 3, p. 309-312.

Table 1. Weekly wastewater loading rate for CRREL test cells (cm/wk).

Application Period	Test Cells					
	Windsor Soil			Charlton Soil		
	1	2	3	4	5	6
June 1973-May 1974	5S* (1)†	10S (2)	5P (2)	5P (2)	10S (2)	5S (1)
June 1974-May 1975	5S (1)	15S (3)	7.5P (3)	7.5P (3)	7.5P **	5S (1)
June 1975-May 1976	5S (1)	15S (3)	7.5P (3)	7.5P (3)	7.5P **	5S (1)
June 1976-May 1977	5S (1)	2.5-12P†† (1-4)	2.5-10P (1-4)	2.5-11P (1-4)	2.5-11P (1-4)	5S (1)
June 1977-May 1978	5S (1)	7.5P (1.5)	7.5P (1.5)	7.5P (1.5)	7.5P (1.5)	5S (1)
June 1978-May 1979	5S,P*** (1)	--	--	--	--	5S,P*** (1)
June 1979- May 1980	5P (1)	--	--	--	--	5P (1)

* S = secondary wastewater; P = primary wastewater.

† Number of daily (8-hour) applications per week.

** Wastewater applied for one 24-hour period per week.

†† Weekly application varied between 2.5 and 12 cm per week.

*** Change from secondary to primary occurred in August 1978.

Table 2. Periods of test cell wastewater application.

Year	Test cell	Application season
1973-1974	1	13 June '73 - 26 Nov '73, 22 Apr '74 - 31 May '74
	2	9 June '73 - 26 Nov '73, 17 Apr '74 - 31 May '74
	3	13 June '73 - 12 Dec '73, 22 Apr '74 - 31 May '74
	4	13 June '73 - 12 Dec '73, 22 Apr '74 - 31 May '74
	5	11 June '73 - 26 Nov '73, 17 Apr '74 - 31 May '74
	6	13 June '73 - 26 Nov '73, 22 Apr '74 - 31 May '74
1974-1975	1	2 June '74 - 31 May '75
	2	2 June '74 - 31 May '75
	3	2 June '74 - 31 May '75
	4	2 June '74 - 31 May '75
	5	2 June '74 - 31 May '75
	6	2 June '74 - 31 May '75
1975-1976	1	16 June '75 - 25 Jan '76, 26 Apr '76 - 31 May '76
	2	16 June '75 - 4 Jan '76, 17 May '76 - 31 May '76
	3	16 June '75 - 30 Nov '75
	4	16 June '75 - 30 Nov '75
	5	16 June '75 - 30 Nov '75
	6	16 June '75 - 31 May '76
1976-1977	1	1 June '76 - 3 Dec '76, 21 Apr '77 - 31 May '77
	2	8 July '76 - 3 Dec '76, 21 Apr '77 - 31 May '77
	3	8 July '76 - 3 Dec '76, 21 Apr '77 - 31 May '77
	4	8 July '76 - 3 Dec '76, 21 Apr '77 - 31 May '77
	5	8 July '76 - 3 Dec '76, 7 Mar '77 - 31 May '77
	6	1 June '76 - 3 Dec '76, 21 Apr '77 - 31 May '77
1977-1978	1	14 June '77 - 6 Sep '77, 10 Apr '78 - 24 May '78
	2	14 June '77 - 6 Sep '77, 16 May '78 - 23 May '78
	3	14 June '77 - 6 Sep '77, 16 May '78 - 22 May '78
	4	15 June '77 - 7 Sep '77, 16 May '78 - 22 May '78
	5	15 June '77 - 7 Sep '77, 16 May '78 - 23 May '78
	6	14 June '77 - 6 Sep '77, 10 Apr '78 - 24 May '78
1978-1979	1	15 June '78 - 16 Nov '78, 30 Apr '79 - 31 May '79
	6	15 June '78 - 16 Nov '78, 30 Apr '79 - 31 May '79
1979-1980	1	1 June '79 - 29 Jan '80, 18 Apr '80 - 30 May '80
	6	1 June '79 - 29 Jan '80, 18 Apr '80 - 30 May '80

Table 3a. Test Cell 1 water balance, 1973-1980.

Period	Wastewater applied (L)	Rainfall (cm)	Rainfall* (L)	Total applied (L)	Percolate (L)	Difference† (L)	Pan evaporation (cm)	Pan evaporation** (L)
June '73-May '74	48,618	92.2	70,800	119,418	ND††	ND	ND	ND
June '74-May '75	114,322	72.9	55,980	170,302	108,841	61,461	66.65	48,545
June '75-May '76	67,047	115.1	88,385	155,432	98,137	57,295	69.49	50,614
June '76-May '77	64,863	98.3	75,485	140,348	89,326	51,022	54.62	39,783
June '77-May '78	48,285	85.7	65,809	114,094	81,661	32,433	52.99	38,596
June '78-May '79	58,437	83.8	64,350	122,787	73,100	49,687	51.29	37,358
June '79-May '80	82,778	55.5	42,618	125,396	88,592	36,804	50.37	36,687
1974-1980 total	435,732	511.3	392,627	828,359	539,657	288,702	345.41	251,583
Annual mean	72,622	85.2	65,438	138,060	89,943	48,117	57.57	41,931

Table 3b. Test Cell 2 water balance, 1973-1980.

Period	Wastewater applied (L)	Rainfall (cm)	Rainfall* (L)	Total applied (L)	Percolate (L)	Difference† (L)	Pan evaporation (cm)	Pan evaporation** (L)
June '73-May '74	120,386	92.2	70,800	191,186	ND††	ND	ND	ND
June '74-May '75	345,650	72.9	55,980	401,630	328,160	73,470	66.65	48,545
June '75-May '76	165,397	115.1	88,385	253,782	184,579	69,203	69.49	50,614
June '76-May '77	62,933	98.3	75,485	138,418	100,405	38,013	54.62	39,783
June '77-May '78	35,481	85.7	65,809	101,290	77,725	23,565	52.99	38,596
June '78-May '79	47,456	83.8	64,350	111,806	68,963	42,843	51.29	37,358
June '79-May '80	54,890	55.5	42,618	97,508	71,566	25,942	50.37	36,687
1974-1980 total	711,807	511.3	392,627	1,104,434	831,398	273,036	345.41	251,583
Annual mean	118,635	85.2	65,438	184,072	138,566	45,506	57.57	41,931

* Converted from centimeters based on a surface area of 76.790 m^2, which includes one-half of the surface of the concrete side walls.

† Considered to be mainly evapotranspiration.

** Converted from centimeters based on a surface area of 72.836 m^2.

†† No data.

Table 3c. Test Cell 3 water balance, 1973-1980.

Period	Wastewater applied (L)	Rainfall (cm)	Rainfall* (L)	Total applied (L)	Percolate (L)	Difference† (L)	Pan evaporation (cm)	Pan evaporation** (L)
June '73-May '74	50,935	92.2	70,800	121,735	ND††	ND	ND	ND
June '74-May '75	170,908	72.9	55,980	226,888	188,062	38,826	66.65	48,545
June '75-May '76	70,004	115.1	88,385	158,389	103,940	54,449	69.49	50,614
June '76-May '77	60,670	98.3	75,485	136,155	95,337	40,818	54.62	39,783
June '77-May '78	36,472	85.7	65,809	102,281	82,630	19,651	52.99	38,596
June '78-May '79	58,097	83.8	64,350	122,447	84,852	37,595	51.29	37,358
June '79-May '80	62,312	55.5	42,618	104,930	78,770	26,160	50.37	36,687
1974-1980 total	458,463	511.3	392,627	851,090	633,591	217,499	345.41	251,583
Annual mean	76,411	85.2	65,438	141,848	105,599	36,250	57.57	41,931

Table 3d. Test Cell 4 water balance, 1973-1980.

Period	Wastewater applied (L)	Rainfall (cm)	Rainfall* (L)	Total applied (L)	Percolate (L)	Difference† (L)	Pan evaporation (cm)	Pan evaporation** (L)
June '73-May '74	50,935	92.2	70,800	121,735	ND††	ND	ND	ND
June '74-May '75	162,528	72.9	55,980	218,508	181,445	37,063	66.65	48,545
June '75-May '76	67,596	115.1	88,385	155,981	120,548	35,433	69.49	50,614
June '76-May '77	61,851	98.3	75,485	137,336	90,057	47,279	54.62	39,783
June '77-May '78	42,032	85.7	65,809	107,841	77,244	30,597	52.99	38,596
June '78-May '79	61,309	83.8	64,350	125,659	82,490	43,169	51.29	37,358
June '79-May '80	45,030	55.5	42,618	87,648	46,188	41,460	50.37	36,687
1974-1980 total	440,346	511.3	392,627	832,973	597,972	235,001	345.41	251,583
Annual mean	73,391	85.2	65,438	138,829	99,662	39,167	57.57	41,931

* Converted from centimeters based on a surface area of 76.790 m^2, which includes one-half of the surface of the concrete side walls.

† Considered to be mainly evapotranspiration.

** Converted from centimeters based on a surface area of 72.836 m^2.

†† No data.

Table 3e. Test Cell 5 water balance, 1973-1980.

Period	Wastewater applied (L)	Rainfall (cm)	Rainfall* (L)	Total applied (L)	Percolate (L)	Difference† (L)	Pan evaporation (cm)	Pan evaporation** (L)
June '73-May '74	101,867	92.2	70,800	172,667	ND††	ND	ND	ND
June '74-May '75	160,961	72.9	55,980	216,941	165,938	51,003	66.65	48,545
June '75-May '76	68,565	115.1	88,385	156,950	117,244	39,706	69.49	50,614
June '76-May '77	74,659	98.3	75,485	150,144	96,552	53,592	54.62	39,783
June '77-May '78	35,378	85.7	65,809	101,187	69,428	31,759	52.99	38,596
June '78-May '79	47,922	83.8	64,350	112,272	65,291	46,981	51.29	37,358
June '79-May '80	58,910	55.5	42,618	101,528	59,069	42,459	50.37	36,687
1974-1980 total	446,395	511.3	392,627	839,022	573,522	295,500	345.41	251,583
Annual mean	74,399	85.2	65,438	139,837	95,587	49,250	57.57	41,931

Table 3f. Test Cell 6 water balance, 1973-1980.

Period	Wastewater applied (L)	Rainfall (cm)	Rainfall* (L)	Total applied (L)	Percolate (L)	Difference† (L)	Pan evaporation (cm)	Pan evaporation** (L)
June '73-May '74	48,618	92.2	70,800	119,418	ND††	ND	ND	ND
June '74-May '75	109,844	72.9	55,980	165,824	129,844	35,980	66.65	48,545
June '75-May '76	92,691	115.1	88,385	181,076	129,303	51,773	69.49	50,614
June '76-May '77	66,154	98.3	75,485	141,639	89,186	52,453	54.62	39,783
June '77-May '78	44,107	85.7	65,809	109,916	69,837	40,079	52.99	38,596
June '78-May '79	59,542	83.8	64,350	123,892	76,343	47,549	51.29	37,358
June '79-May '80	81,166	55.5	42,618	123,784	75,973	47,811	50.37	36,687
1974-1980 total	453,504	511.3	392,627	846,131	570,486	275,645	345.41	251,583
Annual mean	75,584	85.2	65,438	141,022	95,081	45,941	57.57	41,931

* Converted from centimeters based on a surface area of 76.790 m^2, which includes one-half of the surface of the concrete side walls.

† Considered to be mainly evapotranspiration.

** Converted from centimeters based on a surface area of 72.836 m^2.

†† No data.

Table 4a. Yearly water quality analyses for Test Cell 1.

	May '73 - May '74		June '74 - May '75		June '75 - May '76		June '76 - May '77		June '77 - May '78		June '78 - May '79		June '79 - May '80	
	App	Perc	App	Perc	App	Perc	App	Perc	App	Perc	App	Perc	App	Perc
NO_3^-	7.5(18)*	7.2(28)	2.4(40)	7.9(176)	10.2(35)	4.0(168)	4.1(30)	3.8(100)	7.6(20)	5.0(49)	2.7(26)	6.3(82)	0.0(39)	11.3(52)
NH_4^+	22.8(13)	0.0(19)	20.6(38)	0.1(150)	11.1(34)	0.1(167)	21.0(27)	0.0(94)	24.4(20)	0.0(47)	28.6(25)	0.0(82)	27.2(39)	0.4(52)
N(K)†	25.7(20)	0.0(28)	23.6(38)	0.1(150)	12.2(31)	0.4(13)	22.8(30)	0.2(5)	25.3(16)	0.2(18)	38.2(20)	1.1(14)	37.7(26)	0.7(17)
P(T)	13.3(20)	<0.2(28)	7.0(36)	<0.2(79)	6.2(23)	-	6.0(29)	-	6.2(16)	-	7.4(20)	-	6.4(27)	0.02(17)
$PO_4^{\equiv}$	-	-	-	-	-	0.07(41)	-	0.05(36)	4.4(2)	0.02(22)	-	0.03(31)	4.2(5)	0.03(32)
C(O)	51(16)	10(26)	41(34)	9(95)	21(22)	8(92)	55(18)	7(33)	40(5)	-	46(10)	2.7(28)	101(15)	1.9(16)
K^+	10.2(17)	6.8**(23)	7.3(12)	1.8**(5)	13.0(5)	1.0**(7)	13.5(4)	2.4**(3)	11.4(4)	-	9.5(1)	-	-	-
Na^+	-	-	-	-	40.6(5)	43.8**(5)	49.3(4)	50.8**(3)	43.0(5)	-	25.8(1)	-	-	-
Ca^{++}	-	-	-	-	6.5(6)	8.5**(8)	18.6(4)	9.7**(3)	7.7(5)	-	8.3(1)	-	-	-
Mg^{++}	-	-	-	-	2.6(6)	3.0**(8)	3.7(4)	2.7**(3)	2.4(5)	-	2.2(1)	-	-	-
Cl^-	55.6(6)	19.4(6)	35.2(37)	21.9(77)	32.9(18)	16.5(79)	36.7(30)	19.2(100)	33.0(19)	23.6(47)	33.9(11)	21.7(25)	31.9(9)	35.1(11)
pH††	7.6(11)	7.1**(16)	7.5(27)	7.1**(7)	6.7(28)	-	7.3(40)	6.8**(10)	7.7(13)	7.5**(6)	7.6(18)	-	7.6(31)	-
Cond.	484(16)	285**(24)	420(29)	330**(8)	339(28)	-	459(31)	345**(4)	498(13)	343(6)**	600(15)	-	494(29)	-
BOD_5	-	-	26(7)	1.0(16)	49(5)	1.8(13)	52(6)	1.6(19)	53(4)	1.7(8)	62(8)	0.3(12)	120(9)	1.5(10)
TSS	-	-	111(19)	13.5(28)	31(13)	-	42(11)	0.9(8)	57(6)	1.0(9)	56(4)	0.4(10)	141(12)	0.9(10)
VSS	-	-	61(20)	-	24(13)	-	25(10)	0.3(8)	36(6)	0.7(9)	46(4)	0.3(10)	89(8)	0.5(3)
Fecal Col.	-	-	$1.9x10^3$(6)	0(20)	$5.4x10^3$(8)	0(19)	$3.4x10^3$(4)	0(25)	$6.5x10^4$(4)	0(8)	$2.7x10^5$(7)	0(8)	$1.4x10^6$(7)	0(15)
Fecal Strep.	-	-	-	-	-	-	-	-	-	-	-	-	$2.4x10^5$(3)	1(5)

* All values given in mg/L except pH (pH units), conductivity (μmhos/cm) and fecal coliform count (#/100ml); numbers in parentheses are the number of analyses.

† Kjeldahl nitrogen.

** Values refer to samples taken at a depth of 18 inches with suction lysimeters.

†† Median value.

Table 4b. Yearly water quality analyses for Test Cell 2.

	May '73 - May '74		June '74 - May '75		June '75 - May '76		June '76 - May '77		June '77 - May '78		June '78 - May '79	
	App	Perc	App	Perc	App	Perc	App	Perc	App	Perc	App	Perc
NO_3^-	10.3(22)*	10.8(28)	2.5(123)	13.8(211)	10.2(58)	15.4(174)	0.3(43)	12.5(101)	0.8(12)	9.7(34)	0.8(21)	5.6(57)
NH_4^+	21.6(12)	0.02(19)	21.6(113)	3.0(195)	11.3(50)	0.1(170)	31.3(40)	0.0(97)	27.9(13)	0.1(32)	28.7(21)	0.0(57)
N(K)†	24.9(21)	0.1(30)	23.7(110)	2.5(185)	12.3(48)	0.1(14)	30.9(46)	0.0(4)	31.7(12)	0.4(13)	38.3(21)	0.4(8)
P(T)	14.3(21)	<0.2(30)	7.0(106)	<0.2(141)	6.0(49)	-	6.6(47)	-	6.2(12)	-	7.9(19)	-
$PO_4^{\equiv}$	-	-	-	-	-	0.09(46)	-	0.04(35)	-	0.06(17)	-	0.03(10)
C(O)	54(18)	8(48)	42(93)	8(131)	23(30)	5(93)	69(26)	6(33)	69(1)	-	50(15)	-
K^+	18.2(20)	2.7**(23)	8.6(46)	2.7**(11)	10.2(7)	3.7**(9)	13.8(3)	7.6**(5)	-	-	-	-
Na^+	-	-	-	-	42.1(6)	41.4**(7)	46.1(3)	36.7**(5)	-	-	-	-
Ca^{++}	-	-	-	-	6.5(8)	14.2**(11)	23.9(3)	13.8**(5)	-	-	-	-
Mg^{++}	-	-	-	-	2.1(8)	3.1**(11)	4.9(3)	2.5**(5)	-	-	-	-
Cl^-	61.5(7)	23.6(7)	32.9(108)	27.7(142)	27.3(20)	17.5(79)	36.5(38)	35.1(101)	30.9(13)	45.4(34)	37(7)	16.9(14)
pH††	7.5 (16)	7.2(17)	7.5(73)	7.2**(16)	6.7(37)	-	7.2(32)	7.3**(8)	7.6(13)	6.9**(9)	(17)	-
Cond.	500(17)	337**(24)	408(91)	369**(19)	320(39)	-	462(46)	322**(7)	480(13)	449**(6)	583(15)	-
BOD_5	-	-	33(18)	2.1(5)	48(7)	1.6(23)	44(5)	1.3(19)	44(2)	1.0(7)	-	-
TSS	-	-	88(39)	4.6(8)	30(22)	0.2(10)	48(9)	0.9(8)	124(4)	0.9(8)	-	-
VSS	-	-	61(40)	0.05(8)	25(20)	0.0(10)	32(8)	0.67(7)	82(4)	0.5(8)	-	-
Fecal Col.	-	-	$6.0x10^3$(26)	0.0(10)	$4.2x10^3$(11)	0.0(38)	$4.4x10^4$(5)	0(26)	$1.1x10^5$(2)	0(7)	-	-

* All values given in mg/L except pH (pH units), conductivity (μmhos/cm) and fecal coliform count (#/100ml); numbers in parentheses are the number of analyses.

† Kjeldahl nitrogen.

** Values refer to samples taken at a depth of 18 inches with suction lysimeters.

†† Median value.

Table 4c. Yearly water quality analyses for Test Cell 3.

	May '73 - May '74		June '74 - May '75		June '75 - May '76		June '76 - May '77		June '77 - May '78		June '78 - May '79	
	App	Perc	App	Perc	App	Perc	App	Perc	App	Perc	App	Perc
NO_3^-	2.2(18)*	9.0(27)	0.8(126)	7.2(206)	0.3(50)	9.9(155)	0.1(43)	11.5(101)	0.8(12)	7.4(34)	2.9(22)	6.8(58)
NH_4^+	27.4(15)	0.1(17)	22.9(117)	1.9(191)	22.2(51)	0.1(152)	30.9(41)	0.0(97)	27.9(13)	1.0(32)	27.7(22)	0.0(58)
N(K)†	33.0(19)	0.1(25)	26.7(115)	1.6(180)	24.5(41)	0.5(13)	31.6(47)	0.1(4)	32.1(12)	0.1(13)	40.3(20)	0.3(8)
P(T)	13.6(19)	<0.2(24)	7.2(113)	<0.2(136)	6.1(41)	-	6.5(48)	-	6.4(12)	-	9.8(19)	-
$PO_4^{\equiv}$	-	-	-	-	-	0.06(40)	-	0.04(35)	-	0.06(17)	-	0.04(10)
C(O)	58(16)	6(24)	54(97)	8(133)	49(22)	7(73)	64(26)	6(33)	69(1)	-	55(15)	5.9(14)
K^+	6.4(19)	2.5(20)	7.5(44)	1.1**(9)	12.9(8)	1.4**(1)	13.8(3)	7.1**(5)	-	-	-	-
Na^+	-	-	-	-	38.0(8)	-	46.1(3)	39.5**(5)	-	-	-	-
Ca^{++}	-	-	-	-	5.4(9)	24.6**(2)	23.9(3)	14.0**(5)	-	-	-	-
Mg^{++}	-	-	-	-	2.5(9)	1.2**(2)	4.9(3)	2.5**(5)	-	-	-	-
Cl^-	57.8(6)	17.7(6)	37.4(109)	27.1(137)	29.3(18)	30.7(72)	36.4(43)	39.0(101)	31.2(13)	44.9(34)	34.3(9)	19.6(14)
pH††	7.5(11)	7.1**(16)	7.1**(16)	7.2**(18)	6.9(31)	-	7.3(50)	7.1**(10)	7.6(13)	6.5**(9)	7.4(16)	-
Cond.	509(18)	270**(23)	403(91)	339**(17)	358(35)	-	458(47)	308**(7)	485(13)	412**(8)	624(16)	-
BOD_5	-	-	92(20)	1.7(4)	121(9)	1.6(20)	110(6)	2.1(18)	42(2)	0.9(7)	-	-
TSS	-	-	115(42)	1.1(6)	45(19)	0.4(11)	71(10)	1.1(7)	122(4)	1.1(8)	-	-
VSS	-	-	98(43)	0.9(6)	30(19)	0.2(11)	43(9)	0.3(7)	83(4)	0.6(8)	-	-
Fecal Col.	-	-	$2.2x10^5$(24)	0(8)	$2.7x10^5$(8)	1(33)	$3.2x10^5$(5)	0(25)	$8.1x10^4$(2)	0(7)	-	-

* All values given in mg/L except pH (pH units), conductivity (μmhos/cm) and fecal coliform count (#/100ml); numbers in parentheses are the number of analyses.

† Kjeldahl nitrogen.

** Values refer to samples taken at a depth of 18 inches with suction lysimeters.

†† Median value.

Table 4d. Yearly water quality analyses for Test Cell 4.

	May '73 - May '74		June '74 - May '75		June '75 - May '76		June '76 - May '77		June '77 - May '78		June '78 - May '79	
	App	Perc	App	Perc	App	Perc	App	Perc	App	Perc	App	Perc
NO_3^-	2.2(18)*	7.9(26)	0.7(89)	11.0(212)	0.3(49)	8.5(154)	0.2(45)	9.4(95)	0.4(15)	10.1(34)	3.1(22)	6.6(58)
NH_4^+	27.8(15)	0.01(17)	22.9(87)	0.1(194)	22.0(50)	0.1(153)	30.7(43)	0.0(93)	27.3(15)	0.0(32)	27.6(22)	0.0(58)
N(K)†	33.0(19)	0.0(24)	26.8(81)	0.1(183)	24.2(40)	0.2(14)	31.7(47)	0.1(4)	30.9(16)	0.3(13)	39.8(20)	0.2(8)
P(T)	13.7(18)	<0.2(24)	7.6(79)	<0.2(140)	6.0(40)	-	6.4(48)	-	6.0(16)	-	9.6(19)	-
$PO_4^{\equiv}$	-	-	-	-	--	0.09(41)	-	0.04(33)	-	0.06(17)	-	0.04(10)
C(O)	58(16)	12(22)	55(75)	10(126)	49(21)	8(73)	66(28)	9(33)	70(1)	-	55(15)	6.7(14)
K^+	6.4(19)	2.8**(23)	7.6(22)	4.9**(10)	12.5(8)	2.9**(12)	14.1(4)	4.5**(5)	-	-	-	-
Na^+	-	-	-	-	37.0(8)	36.8**(11)	46.3(4)	34.3**(5)	-	-	-	-
Ca^{++}	-	-	-	-	5.3(9)	13.2**(13)	18.4(4)	14.9**(5)	-	-	-	-
Mg^{++}	-	-	-	-	2.4(9)	1.5**(13)	4.2(4)	2.3**(5)	-	-	-	-
Cl^-	57.8(6)	15.3(6)	36.1(75)	25.7(142)	29.0(18)	72.9(64)	36.8(45)	58.9(96)	31.2(16)	45.2(34)	35.1(9)	15.2(15)
pH††	7.5 (11)	7.1**(15)	7.4(51)	7.2**(20)	7.0(30)	-	7.3(44)	6.9**(8)	7.7(9)	6.4**(13)	7.4(16)	-
Cond.	509(18)	252**(22)	409(63)	341**(19)	355(34)	-	461(49)	312**(7)	473(9)	440(13)**	618(16)	-
BOD_5	-	-	83(18)	1.5(5)	117(9)	1.5(22)	87(7)	1.6(18)	-	0.5(7)	-	0.5(1)
TSS	-	-	100(31)	0.9(8)	44(18)	0.6(11)	65(9)	1.0(7)	146(1)	1.4(6)	-	0.1(1)
VSS	-	-	75(32)	0.5(8)	30(19)	0.2(11)	48(8)	0.7(7)	121(1)	1.0(6)	-	-
Fecal Col.	-	-	$2.6x10^5$(18)	0(9)	$2.6x10^5$(9)	1(31)	$2.1x10^5$(5)	0(23)	$3.6x10^3$(1)	0(7)	-	7(1)

* All values given in mg/L except pH (pH units), conductivity (μmhos/cm) and fecal coliform count (#/100ml); numbers in parentheses are the number of analyses.

† Kjeldahl nitrogen.

** Values refer to samples taken at a depth of 18 inches with suction lysimeters.

†† Median value.

Table 4e. Yearly water quality analyses for Test Cell 5.

	May '73 - May '74		June '74 - May '75		June '75 - May '76		June '76 - May '77		June '77 - May '78		June '78 - May '79	
	App	Perc	App	Perc	App	Perc	App	Perc	App	Perc	App	Perc
NO_3^-	4.9(17)*	9.3(23)	1.4(54)	11.9(175)	0.2(25)	5.8(151)	0.1(47)	9.0(98)	0.4(15)	12.4(33)	0.8(21)	4.5(55)
NH_4^+	20.9(10)	0.0(17)	21.7(53)	0.0(154)	20.7(26)	0.0(150)	31.4(44)	0.0(92)	27.3(15)	0.0(31)	28.7(21)	0.0(55)
N(K)†	22.1(19)	0.0(26)	25.3(51)	0.1(152)	23.8(24)	0.4(14)	31.6(49)	0.4(4)	31.0(16)	0.1(13)	38.3(20)	0.2(8)
P(T)	10.9(19)	<0.2(26)	7.1(51)	<0.2(79)	6.5(24)	-	6.4(50)	-	6.0(16)	-	8.0(18)	-
$PO_4^=$	-	-	-	-	-	0.06(43)	-	0.05(34)	-	0.07(17)	-	0.04(10)
C(O)	51(15)	9(20)	54(47)	9(96)	42(13)	8(71)	68(31)	7(32)	70(1)	-	49.5(15)	3.3 14)
K^+	13.4(16)	3.7**(19)	7.5(13)	1.6**(6)	13.4(7)	3.2**(11)	14.4(5)	4.7**(5)	-	-	-	-
Na^+	-	-	-	-	38.1(7)	39.1**(8)	46.3(5)	41.2**(5)	-	-	-	-
Ca^{++}	-	-	-	-	5.5(7)	14.0**(12)	17.8(5)	21.6**(5)	-	-	-	-
Mg^{++}	-	-	-	-	2.5(7)	1.4**(12)	4.1(5)	3.4**(5)	-	-	-	-
Cl^-	62.0(6)	20.4(6)	34.3(46)	25.0(54)	28.7(12)	23.8(64)	36.7(47)	38.8(98)	31.2(17)	47.7(33)	37.5(7)	13.2(14)
pH††	7.6(13)	7.1**(15)	7.4(34)	7.1**(6)	6.9(19)	-	7.3(60)	6.4**(10)	7.7(9)	6.4**(12)	7.4(17)	-
Cond.	476(18)	295**(23)	394(37)	348**(11)	436(20)	-	462(51)	398**(7)	471(10)	383**(12)	561(15)	-
BOD_5	-	-	86(10)	0.9(21)	85(4)	1.4(21)	89(6)	1.3(19)	-	0.3(7)	26(1)	1.4(1)
TSS	-	-	61(20)	2.7(26)	47(14)	0.4(11)	70(9)	0.8(8)	146(1)	1.0(6)	-	0.2(1)
VSS	-	-	43(21)	1.3(28)	28(14)	0.2(11)	49(8)	0.3(8)	121(1)	0.8(6)	-	-
Fecal Col.	-	-	$2.4x10^5$ (11)	$3.8x10^2$ (28)	$2.7x10^5$ (6)	0(31)	$2.6x10^5$ (5)	0(24)	$3.6x10^3$ (1)	0(7)	-	0(1)

* All values given in mg/L except pH (pH units), conductivity (μmhos/cm) and fecal coliform count (#/100ml); numbers in parentheses are the number of analyses.

† Kjeldahl nitrogen.

** Values refer to samples taken at a depth of 18 inches with suction lysimeters.

†† Median value.

Table 4f. Yearly water quality analyses for Test Cell 6.

	May '73 - May '74		June '74 - May '75		June '75 - May '76		June '76 - May '77		June '77 - May '78		June '78 - May '79		June '79 - May '80	
	App	Perc	App	Perc	App	Perc	App	Perc	App	Perc	App	Perc	App	Perc
NO_3^-	5.7(17)*	5.8(27)	2.3(40)	9.0(180)	8.9(45)	5.5(166)	4.2(30)	5.3(99)	7.2(20)	3.5(48)	2.7(27)	7.9(80)	0.0(39)	10.1(52)
NH_4^+	22.8(13)	0.1(18)	20.6(38)	0.0(154)	11.5(43)	0.0(162)	21.4(27)	0.1(95)	24.7(20)	0.0(47)	28.1(26)	0.0(80)	27.9(39)	0.1(52)
N(K)†	25.7(20)	0.0(26)	23.6(38)	0.1 (155)	12.7(37)	0.2(11)	22.5(30)	0.1(4)	25.6(16)	2.8(18)	38.2(21)	0.7(15)	39.5(26)	0.4(17)
P(T)	13.3(20)	<0.2(27)	7.0(36)	<0.2(81)	5.8(37)	-	6.0(29)	-	6.2(16)	-	7.5(21)	-	6.5(27)	0.03(17)
$PO_4^{\equiv}$	-	-	-	-	-	0.05(40)	-	0.04(36)	4.4(2)	0.02(22)	-	0.03(30)	4.4(4)	0.03(32)
C(O)	51(16)	11(24)	42(34)	10(101)	20(27)	7(95)	52(18)	8(32)	41(5)	-	47(19)	2.5(27)	101(15)	1.8(12)
K^+	10.2(17)	2.0**(22)	7.2(12)	2.8**(5)	12.5(5)	1.6**(12)	13.2(4)	0.9**(5)	11.4(5)	1.6**(4)	9.5(1)	-	-	-
Na^+	-	-	-	-	38.2(5)	40.5**(11)	49.0(4)	33.5**(5)	42.7(5)	47.5**(4)	25.8(1)	-	-	-
Ca^{++}	-	-	-	-	6.6(6)	14.2**(13)	19.1(4)	11.2**(5)	7.8(5)	17.7**(4)	8.3(1)	-	-	-
Mg^{++}	-	-	-	-	2.6(6)	1.1**(13)	3.7(4)	1.9**(5)	2.4(5)	2.2**(4)	2.2(1)	-	-	-
Cl^-	55.6(6)	19.3(6)	35.4(37)	25.2(79)	34.5(28)	23.4(49)	37.5(30)	17.8(98)	33.2(19)	36.0(47)	33.7(11)	23.0(24)	33.0(9)	32.7(11)
pH††	7.6(11)	7.3**(15)	7.5(27)	7.1**(8)	6.7(35)	-	7.3(46)	7.0**(8)	7.7(13)	6.3**(11)	7.6(19)	-	7.6(31)	-
Cond.	484(16)	256**(21)	425(29)	363**(9)	347(33)	-	458(31)	300**(7)	501(13)	439**(11)	598(16)	-	502(29)	-
BOD_5	-	-	30(7)	0.6(17)	33(10)	1.2(14)	52(6)	1.2(19)	52(4)	0.6(8)	62(8)	0.4(11)	123(9)	1.5(10)
TSS	-	-	103(19)	0.8(26)	35(19)	-	42(11)	1.0(8)	57(6)	0.7(9)	55(4)	0.5(9)	147(12)	1.6(12)
VSS	-	-	65(20)	0.2(28)	24(19)	-	25(10)	0.2(7)	36(6)	0.5(8)	46(4)	0.3(9)	91(8)	1.0(4)
Fecal Col.	-	-	$6.2x10^3$ (6)	1(22)	$4.3x10^3$ (11)	0(19)	$3.3x10^3$ (4)	0(25)	$6.3x10^4$ (4)	0(8)	$2.7x10^5$(7)	0(8)	$1.4x10^6$(7)	1(13)
Fecal Strep.	-	-	-	-	-	-	-	-	-	-	-	-	$2.0x10^5$(4)	0(7)

* All values given in mg/L except pH (pH units), conductivity (μmhos/cm) and fecal coliform count (#/100ml); numbers in parentheses are the number of analyses.

† Kjeldahl nitrogen.

** Values refer to samples taken at a depth of 18 inches with suction lysimeters.

†† Median value.

Table 5a. Test Cell 1 plant harvest data.

Date	Yield (dry wt.) (kg/cell)	N (%)	N uptake (kg/cell)	N uptake (kg/ha)	P (%)	P uptake (kg/cell)	P uptake (kg/ha)
1973-74 July	7.39	2.74	0.202	52.3	0.29	0.0214	5.54
Sept	6.99	3.78	0.214	68.4	0.29	0.0203	5.26
June	17.98	3.75	0.674	174.6	0.39	0.0701	18.17
Total*	32.36	--	1.090	295.3	--	0.1118	28.97
1974-75 July	16.50	2.96	0.488	126.4	0.31	0.0512	13.26
Sept	17.93	2.90	0.520	134.7	0.35	0.0628	16.26
June	27.58	2.72	0.750	194.3	0.15	0.0414	10.73
Total	62.01	--	1.758	455.4	--	0.1554	40.25
1975-76 July	17.60	2.30	0.405	104.9	0.29	0.0510	13.21
Sept	7.26	3.70	0.269	69.7	0.38	0.0276	7.15
June	19.26	2.30	0.443	114.8	0.21	0.0501	12.98
Total	44.12	--	1.120	290.4	--	0.1287	33.34
1976-77 Aug	14.15	2.80	0.396	102.6	0.28	0.0396	10.26
Sept	4.00	3.40	0.136	35.2	0.43	0.0172	4.46
June	16.85	2.43	0.409	106.0	0.41	0.0691	17.90
Total	35.00	--	0.941	243.8	--	0.1259	32.62
1977-78 July	19.94	3.66	0.730	189.1	0.43	0.0857	22.20
Oct	9.80	2.87	0.281	72.8	0.39	0.0382	9.90
June	18.00	2.60	0.468	121.2	0.39	0.0702	18.19
Total	47.74	--	1.479	383.1	--	0.1941	50.29
1978-79 July	11.98	2.80	0.335	86.8	0.40	0.0479	12.41
Sept	22.68	2.58	0.585	151.6	0.36	0.0816	21.14
June	15.70	3.66	0.575	149.0	0.45	0.0707	18.32
Total	50.36	--	1.495	387.4	--	0.2002	51.87
1979-80 July	8.82	2.94	0.259	67.1	0.33	0.0291	7.54
Sept	8.44	2.58	0.218	56.5	0.44	0.0371	9.61
June	17.10	3.78	0.646	167.4	0.38	0.0650	16.84
Total	34.36	--	1.123	291.0	--	0.1312	33.99

*The yearly totals are calculated to correspond to the way in which the water quality results were obtained.

Table 5b. Test Cell 2 plant harvest data.

Date	Yield (dry wt.) (kg/cell)	N (%)	N uptake (kg/cell)	N uptake (kg/ha)	P (%)	P uptake (kg/cell)	P uptake (kg/ha)
1973-74 July	8.03	2.84	0.228	59.1	0.27	0.0217	5.62
Sept	10.34	4.82	0.498	129.0	0.27	0.0279	7.23
June	20.40	3.82	0.779	201.9	0.40	0.0816	21.14
Total*	38.77	--	1.505	390.0	--	0.1312	33.99
1974-75 July	20.89	3.17	0.662	171.6	0.27	0.0564	14.61
Sept	26.50	3.42	0.906	234.8	0.35	0.0928	24.03
June	31.38	3.58	1.123	290.9	0.18	0.0565	14.64
Total	78.77	--	2.691	697.3	--	0.2057	53.28
1975-76 July	21.81	3.40	0.742	192.2	0.37	0.0807	20.91
Sept	10.29	3.20	0.329	85.2	0.40	0.0412	10.67
Total	32.10	--	1.071	277.5	--	0.1219	31.58
1976-77 Sept	11.43	3.50	0.400	103.6	0.47	0.0537	13.91
June	11.06	2.28	0.252	65.3	0.43	0.0476	12.33
Total	22.49	--	0.652	168.9	--	0.1013	26.24
1977-78 July	18.74	2.48	0.465	120.5	0.41	0.0768	19.90
Oct	14.27	2.56	0.365	94.6	0.42	0.0599	15.52
Total	33.01	--	0.830	215.0	--	0.1367	35.42

Table 5c. Test Cell 3 plant harvest data.

Date	Yield (dry wt.) (kg/cell)	N (%)	N uptake (kg/cell)	N uptake (kg/ha)	P (%)	P uptake (kg/cell)	P uptake (kg/ha)
1973-74 July	5.81	2.46	0.143	37.0	0.28	0.0163	4.22
Sept	8.21	3.78	0.310	80.3	0.28	0.0230	5.96
June	15.98	3.69	0.590	152.8	0.36	0.0575	14.90
Total*	28.33	--	1.043	270.1	--	0.0968	25.08
1974-75 July	17.85	3.82	0.682	176.7	0.31	0.0553	14.33
Sept	22.73	2.98	0.677	175.4	0.28	0.0636	16.49
June	23.10	3.31	0.765	198.2	0.18	0.0416	10.78
Total	63.68	--	2.124	550.3	--	0.1605	41.60
1975-76 July	17.52	2.90	0.508	131.6	0.32	0.0561	14.53
Sept	9.33	2.60	0.243	63.0	0.37	0.0345	8.94
Total	26.85	--	0.751	194.6	--	0.0906	23.47
1976-77 Sept	15.22	3.00	0.457	118.4	0.21	0.0320	8.29
June	12.11	2.56	0.310	80.3	0.37	0.0448	11.61
Total	27.33	--	0.767	198.7	--	0.0768	19.90
1977-78 July	19.62	2.66	0.522	135.2	0.42	0.0824	21.35
Oct	14.03	1.92	0.269	69.7	0.39	0.0547	14.17
Total	33.65	--	0.791	204.9	--	0.1371	35.52

*The yearly totals are calculated to correspond to the way in which the water quality results were obtained.

Table 5d. Test Cell 4 plant harvest data.

Date	Yield (dry wt.) (kg/cell)	N (%)	N uptake (kg/cell)	N uptake (kg/ha)	P (%)	P uptake (kg/cell)	P uptake (kg/ha)
1973-74 July	10.03	2.62	0.263	68.1	0.29	0.0291	7.54
Sept	10.48	3.90	0.409	106.0	0.29	0.0304	7.88
June	15.72	3.71	0.583	151.1	0.36	0.0566	14.66
Total*	36.23	--	1.255	325.2	--	0.1161	30.08
1974-75 July	13.56	3.14	0.426	110.3	0.25	0.0339	8.78
Sept	26.23	2.79	0.732	189.6	0.30	0.0787	20.38
June	23.07	3.32	0.766	198.5	0.18	0.0415	10.75
Total	62.86	--	1.924	498.4	--	0.1541	39.92
1975-76 July	17.26	2.90	0.500	129.5	0.35	0.0604	15.65
Sept	9.49	3.30	0.313	81.1	0.35	0.0332	8.60
Total	26.75	--	0.813	210.6	--	0.0936	24.25
1976-77 Sept	9.17	3.30	0.303	78.5	0.51	0.0468	12.12
June	12.88	2.34	0.301	78.0	0.38	0.0489	12.67
Total	22.05	--	0.604	156.5	--	0.0957	24.79
1977-78 July	18.74	1.85	0.347	89.9	0.44	0.0825	21.37
Oct	17.27	2.41	0.416	107.8	0.35	0.0604	15.65
Total	36.01	--	0.763	197.7	--	0.1429	37.02

Table 5e. Test Cell 5 plant harvest data.

Date	Yield (dry wt.) (kg/cell)	N (%)	N uptake (kg/cell)	N uptake (kg/ha)	P (%)	P uptake (kg/cell)	P uptake (kg/ha)
1973-74 July	13.70	2.74	0.375	97.2	0.28	0.0384	9.95
Sept	8.26	4.18	0.345	89.4	0.28	0.0231	5.98
June	16.65	3.88	0.646	167.4	0.39	0.0649	16.82
Total*	38.61	--	1.366	354.0	--	0.1264	32.75
1974-75 July	21.01	2.37	0.498	129.0	0.20	0.4200	10.88
Sept	28.73	2.99	0.859	222.6	0.29	0.0833	21.59
June	24.65	2.38	0.587	152.1	0.16	0.0394	10.21
Total	74.39	--	1.944	503.7	--	0.1647	42.68
1975-76 July	19.89	3.40	0.676	175.1	0.33	0.0597	15.47
Sept	11.80	2.70	0.319	82.6	0.34	0.0401	10.39
Total	31.69	--	0.995	257.8	--	0.0998	25.86
1976-77 Sept	9.87	3.00	0.296	76.7	0.42	0.0415	10.75
June	22.24	2.03	0.451	116.8	0.33	0.0734	19.02
Total	32.11	--	0.747	193.5	--	0.1149	29.77
1977-78 July	20.47	3.20	0.655	169.7	0.36	0.0737	19.09
Oct	17.15	2.40	0.412	106.7	0.38	0.0652	16.89
Total	37.62	--	1.067	276.4	--	0.1389	35.99

*The yearly totals are calculated to correspond to the way in which the water quality results were obtained.

Table 5f. Test Cell 6 plant harvest data.

Date	Yield (dry wt.) (kg/cell)	N (%)	N uptake (kg/cell)	N uptake (kg/ha)	P (%)	P uptake (kg/cell)	P uptake (kg/ha)
1973-74 July	11.48	2.66	0.305	79.0	0.26	0.0298	7.72
Sept	6.99	3.46	0.242	62.7	0.26	0.0182	4.72
June	18.91	3.59	0.679	175.9	0.39	0.0737	19.09
Total*	37.38	--	1.226	317.6	--	0.1217	31.53
1974-75 July	15.89	2.68	0.426	110.3	0.21	0.0334	8.65
Sept	18.41	3.10	0.571	147.9	0.23	0.0423	10.96
June	16.17	3.80	0.614	159.1	0.18	0.0291	7.54
Total	50.47	--	1.611	417.3	--	0.1048	27.15
1975-76 July	16.67	2.70	0.450	116.6	0.22	0.0367	9.51
Sept	9.71	3.20	0.311	80.6	0.29	0.0282	7.31
June	21.86	2.30	0.503	130.3	0.29	0.0634	16.43
Total	48.24	--	1.264	327.5	--	0.1283	33.24
1976-77 July	26.35	1.90	0.501	129.8	0.22	0.0580	15.03
Sept	3.45	3.30	0.114	29.5	0.36	0.0124	3.21
June	17.80	2.54	0.452	117.1	0.45	0.0801	20.75
Total	47.60	--	1.067	276.4	--	0.1505	38.99
1977-78 July	19.67	1.58	0.311	80.6	0.35	0.0688	17.82
Oct	16.04	2.46	0.395	102.3	0.33	0.0529	13.71
June	19.09	2.83	0.540	139.9	0.41	0.0783	20.29
Total	54.80	--	1.246	322.8	--	0.2000	51.81
1978-79 July	11.49	2.74	0.315	81.6	0.45	0.0517	13.39
Sept	17.21	3.24	0.558	144.6	0.32	0.0551	14.27
June	13.92	2.64	0.367	95.1	0.36	0.0501	12.98
Total	42.62	--	1.240	321.3	--	0.1569	40.65
1979-80 July	8.66	3.22	0.279	72.4	0.34	0.0295	7.64
Sept	5.98	3.62	0.216	56.0	0.45	0.0269	6.97
June	23.24	3.30	0.767	198.7	0.38	0.0883	22.88
Total	37.88	--	1.262	327.1	--	0.1447	37.49

*The yearly totals are calculated to correspond to the way in which the water quality results were obtained.

Table 6. Plant concentrations of potassium (%).

Date		Test Cell 1	2	3	4	5	6
1973-74	July	2.30	2.30	2.30	2.40	2.50	2.20
	Sept	2.30	2.30	2.30	2.40	2.50	2.20
	June	3.00	3.10	2.85	2.84	3.08	3.08
1974-75	July	2.55	2.60	2.55	2.38	1.89	1.98
	Sept	2.46	2.46	2.04	2.39	2.41	1.87
	June	2.18	2.52	2.51	2.84	1.74	2.86
1975-76	July	1.99	2.49	2.16	2.46	2.30	1.84
	Sept	2.13	2.40	1.99	1.77	2.16	1.96
	June	1.77	----	----	----	----	2.06
1976-77	Aug	1.86	----	----	----	----	1.45
	Sept	2.49	3.42	1.90	2.99	3.41	1.98
	June	3.76	4.77	4.77	4.78	4.01	4.44
1977-78	July	3.43	3.14	3.81	3.97	2.40	2.82
	Oct	2.98	3.44	3.41	3.49	3.42	2.99
	June	3.99	----	----	----	----	3.93
1978-79	July	3.33	----	----	----	----	3.29
	Sept	2.46	----	----	----	----	2.91
	June	3.76	----	----	----	----	3.35
1979-80	July	2.86	----	----	----	----	3.17
	Sept	3.17	----	----	----	----	3.10
	June	2.95	----	----	----	----	2.86

Table 7. Protein and Total Digestable Nutrients (TDN) in plant material (%).

Date sampled	*Cell no.*	*Protein*	*TDN*
Sept 1975	1,6	15.1	63
Sept 1975	3,4,5	21.0	68
Sept 1975	2	20.8	67
Aug 1976	1	15.5	53
Aug 1976	6	15.4	59
Sept 1976	4	20.3	56
Sept 1976	5	18.7	51
Sept 1979	1	20.2	68
Sept 1979	2	18.7	65
Sept 1979	3	21.4	67
Sept 1979	4	19.0	64
Sept 1979	5	19.6	65
Sept 1979	6	29.2	70

Table 8a. Test Cell 1 nutrient balance sheet, 1973-1980.

Period	Nitrogen (kg/cell)				Phosphorus (kg/cell)			
	Applied*	Plant uptake	Percolate	Unaccounted for	Applied*	Plant uptake	Percolate	Unaccounted for
June 1973 - May 1974	1.61	1.090 (67.7%)	--	--	0.647	0.1118 (17.3%)	--	--
June 1974 - May 1975	2.97	1.758 (59.2%)	0.875 (29.5%)	0.337 (11.3%)	0.804	0.1554 (19.3%)	<0.0181 (2.2%)	0.6306 (78.4%)
June 1975 - May 1976	1.50	1.120 (74.7%)	0.431 (28.7%)	-0.051 (-3.4%)	0.417	0.1287 (30.9%)	0.0065 (1.6%)	0.2818 (67.6%)
June 1976 - May 1977	1.74	0.941 (54.1%)	0.361 (20.7%)	0.438 (25.2%)	0.392	0.1259 (32.1%)	0.0046 (1.2%)	0.2615 (66.7%)
June 1977 - May 1978	1.59	1.479 (93.0%)	0.421 (26.5%)	-0.310 (-19.5%)	0.300	0.1941 (64.7%)	0.0015 (0.5%)	0.1044 (34.8%)
June 1978 - May 1979	2.39	1.495 (62.6%)	0.540 (22.6%)	0.355 (14.9%)	0.433	0.2002 (46.2%)	0.0021 (0.5%)	0.2307 (53.3%)
June 1979 - May 1980	3.22	1.123 (34.9%)	1.063 (32.6%)	1.034 (32.1%)	0.533	0.1312 (24.6%)	0.0026 (0.5%)	0.3992 (74.9%)
Total 1974 - 1980	13.41	7.916 (59.0%)	3.691 (27.5%)	1.803 (13.4%)	2.879	0.9355 (32.5%)	0.0354 (1.2%)	1.9082 (66.3%)

*Refers only to amount entering system in wastewater.

Table 8b. Test Cell 2 nutrient balance sheet, 1973-1978.

Period	Nitrogen (kg/cell)				Phosphorus (kg/cell)			
	Applied*	Plant uptake	Percolate	Unaccounted for	Applied*	Plant uptake	Percolate	Unaccounted for
June 1973 - May 1974	4.24	1.505 (35.5%)	--	--	1.722	0.1312 (7.6%)	--	--
June 1974 - May 1975	9.03	2.691 (29.8%)	5.349 (59.2%)	0.990 (11.0%)	2.410	0.2057 (8.5%)	<0.066 (2.7%)	2.138 (88.7%)
June 1975 - May 1976	3.72	1.071 (28.8%)	2.847 (76.5%)	-0.198 (-5.3%)	0.988	0.1219 (12.3%)	0.0164 (1.7%)	0.8497 (86.0%)
June 1976 - May 1977	1.96	0.652 (33.3%)	1.257 (64.1%)	0.051 (2.6%)	0.412	0.1013 (24.6%)	0.0042 (1.0%)	0.3065 (74.4%)
June 1977 - May 1978	1.86	0.830 (44.6%)	0.414 (22.3%)	0.616 (33.1%)	0.377	0.1367 (36.2%)	0.0023 (0.6%)	0.238 (63.1%)
Total 1974-1978	16.57	5.244 (31.6%)	9.867 (59.5%)	1.459 (8.8%)	4.187	0.5656 (13.5%)	0.0889 (2.1%)	3.532 (84.4%)

Table 8c. Test Cell 3 nutrient balance sheet, 1973-1978.

Period	Nitrogen (kg/cell)				Phosphorus (kg/cell)			
	Applied*	Plant uptake	Percolate	Unaccounted for	Applied*	Plant uptake	Percolate	Unaccounted for
June 1973 - May 1974	1.79	1.043 (58.3%)	-	-	0.693	0.0968 (14.0%)	-	-
June 1974 - May 1975	4.70	2.124 (45.2%)	1.64 (34.9%)	0.936 (19.9%)	1.236	0.1605 (13.0%)	<0.038 (3.1%)	1.0375 (83.9%)
June 1975 - May 1976	1.74	0.751 (43.2%)	1.07 (61.5%)	-0.081 (-4.7%)	0.427	0.0906 (21.2%)	0.0058 (1.4%)	0.3306 (77.4%)
June 1976 - May 1977	1.92	0.767 (39.9%)	1.11 (57.8%)	0.043 (2.2%)	0.391	0.0768 (19.6%)	0.0040 (1.0%)	0.3102 (79.3%)
June 1977 - May 1978	1.20	0.791 (65.9%)	0.61 (50.8%)	-0.201 (-16.7%)	0.567	0.1371 (24.2%)	0.0034 0.6%)	0.4265 (75.2%)
Total 1974-1978	9.56	4.433 (46.4%)	4.43 (46.3%)	0.697 (7.3%)	2.621	0.4650 (17.7%)	0.0512 (2.0%)	2.1048 (80.3%)

*Refers only to amount entering system in wastewater.

Table 8d. Test Cell 4 nutrient balance sheet, 1973-1978.

Period	Nitrogen (kg/cell)				Phosphorus (kg/cell)			
	Applied*	Plant uptake	Percolate	Unaccounted for	Applied*	Plant uptake	Percolate	Unaccounted for
June 1973 - May 1974	1.79	1.255 (70.1%)	-	-	0.698	0.1161 (16.6%)	-	-
June 1974 - May 1975	4.48	1.924 (42.9%)	2.02 (45.1%)	0.534 (11.9%	1.232	0.1541 (12.5%)	<0.0360 (2.9%)	1.0419 (84.6%)
June 1975 - May 1976	1.66	0.813 (48.9%)	1.05 (63.3%)	-0.203 (-12.2%)	0.407	0.0936 (23.0%)	0.0113 (2.8%)	0.3021 (74.2%)
June 1976 - May 1977	1.97	0.604 (30.7%)	0.85 (43.1%)	0.516 (26.2%)	0.395	0.0957 (24.2%)	0.0034 (0.9%)	0.2959 (74.9%)
June 1977 - May 1978	1.32	0.763 (57.8%)	0.80 (60.6%)	-0.243 (-18.4%)	0.254	0.1429 (56.3%)	0.0048 (1.9%)	0.1063 (41.9%)
Total 1974 - 1978	9.43	4.104 (43.5%)	4.72 (50.1%)	0.604 (6.4%)	2.288	0.4863 (21.3%)	0.0555 (2.4%)	1.7462 (76.3%)

Table 8e. Test Cell 5 nutrient balance sheet, 1973-1978.

Period	Nitrogen (kg/cell)				Phosphorus (kg/cell)			
	Applied*	Plant uptake	Percolate	Unaccounted for	Applied*	Plant uptake	Percolate	Unaccounted for
June 1973 - May 1974	2.75	1.366 (49.7%)	-	-	1.110	0.1264 (11.4%)	-	-
June 1974 - May 1975	4.29	1.944 (45.3%)	1.981 (46.2%)	0.365 (8.5%)	1.145	0.1647 (14.4%)	<0.033 (2.9%)	0.9473 (82.7%)
June 1975 - May 1976	1.65	0.995 (60.3%)	0.733 (44.4%)	-0.078 (-4.7%)	0.444	0.0998 (22.5%)	0.0076 (1.7%)	0.3366 (75.8%)
June 1976 - May 1977	2.37	0.747 (31.5%)	0.914 (38.6%)	0.709 (29.9%)	0.477	0.1149 (24.1%)	0.0049 (1.0%)	0.3572 (74.9%)
June 1977 - May 1978	1.11	1.067 (96.1%)	0.871 (78.5%)	-0.828 (-74.6%)	0.213	0.1389 (65.2%)	0.0050 (2.3%)	0.0691 (32.4%)
Total 1974 - 1978	9.42	4.753 (50.5%)	4.499 (47.8%)	0.168 (1.8%)	2.279	0.5183 (22.7%)	0.0505 (2.2%)	1.7102 (75.0%)

*Refers only to amount entering system in wastewater.

Table 8f. Test Cell 6 nutrient balance sheet, 1973-1980.

Period	Nitrogen (kg/cell)				Phosphorus (kg/cell)			
	Applied*	Plant uptake	Percolate	Unaccounted for	Applied*	Plant uptake	Percolate	Unaccounted for
June 1973 - May 1974	1.61	1.226 (76.1%)	-	-	0.647	0.1217 (18.8%)	-	-
June 1974 - May 1975	2.85	1.611 (56.5%)	1.183 (41.5%)	0.056 (2.0%)	0.768	0.1048 (13.6%)	<0.0260 (3.4%)	0.6372 (83.0%)
June 1975 - May 1976	2.00	1.264 (63.2%)	0.743 (37.1%)	-0.007 (0.4%)	0.541	0.1283 (23.7%)	0.0064 (1.2%)	0.4063 (75.1%)
June 1976 - May 1977	1.76	1.067 (60.6%)	0.482 (27.4%)	0.211 (12.0%)	0.400	0.1505 (37.6%)	0.0036 (0.9%)	0.2459 (61.5%)
June 1977 - May 1978	1.45	1.246 (85.9%)	0.441 (30.4%)	-0.237 (-16.3%)	0.273	0.2000 (73.3%)	0.0013 (0.5%)	0.0717 (26.3%)
June 1978 - May 1979	2.43	1.240 (51.0%)	0.654 (26.9%)	0.536 (22.1%)	0.444	0.1569 (35.3%)	0.0024 (0.5%)	0.2847 (64.1%)
June 1979 - May 1980	3.21	1.262 (39.3%)	0.797 (24.8%)	1.151 (35.9%)	0.531	0.1447 (27.3%)	0.0024 (0.5%)	0.3839 (72.3%)
Total 1974 - 1980	13.70	7.690 (56.1%)	4.300 (31.4%)	1.710 (12.5%)	2.957	0.8852 (29.9%)	0.0421 (1.4%)	2.0297 (68.6%)

*Refers only to amount entering system in wastewater.

Table 9. Soil amendments applied (kg/ha) to test cells, 1973 - 1980.

Date of Treatment	Test Cell 1	2	3	4	5	6
Lime*						
October 1975	504	1497	1329	1497	1497	1665
28-29 May 1976	-	4492	3988	4492	4492	-
2 May 1977	2200	2200	2200	2200	2200	2200
1978	-	-	-	-	-	-
Total	2704	8189	7517	8189	8189	3865
Potassium†						
28-29 May 1976	-	300	300	300	300	-
2 May 1977	300	300	300	300	300	300
4 May 1978	137	-	-	-	-	137
Total	437	600	600	600	600	437
Phosphorus**						
9 August 1976	-	41	41	81	81	-
4 May 1979	136	-	-	-	-	136
30 April 1980	140	-	-	-	-	140
Total	276	41	41	81	81	276

* Applied as dolomitic limestone ($CaMgCO_3$).

† Applied as potassium chloride fertilizer (KCl).

** Applied as superphosphate fertilizer (0-20-0).

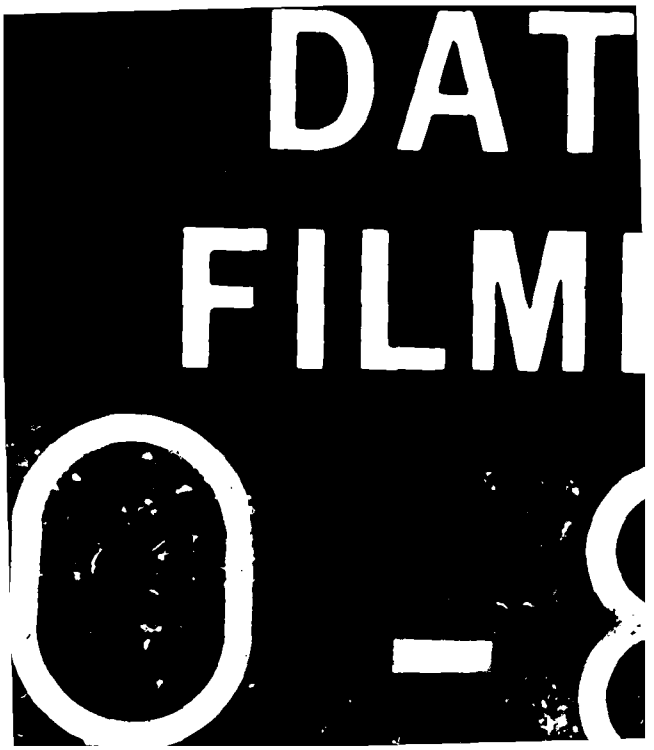
Table 10. Removal of "spiked" volatile toxic organics, 1979-80.*

Substance	Mean concentration (µg/L) Wastewater before spraying	Wastewater after spraying	Test cell percolates Cell 1	Cell 6
Chloroform	41.8	14.0	0.86 (9)†	0.73 (11)
Toluene	57.3	24.4	0 06 (10)	0.02 (12)
Methylene chloride	7.61	2.32	0.06 (5)	0.04 (6)
1,1 dichloroethane	30.2	9.88	b.d. (6)	0.06 (6)
Bromodichloromethane	11.1	3.98	b.d.**(2)	0.01 (3)
Tetrachloroethylene	61.9	22.7	0.08 (7)	0.35 (7)

* Taken from Jenkins and Palazzo (in press).

† Numbers in parentheses refer to total number of analyses for that substance.

** Below a detection limit of about 0.01 µg/L.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